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Firms‘ knowledge acquisition during dual-track VET: Which sources are important for innovativeness?

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Abstract

Researchers debate for more than 3 decades on the effect of vocational training on innovations. While some studies show a negative effect of vocational education that firms organize on its own, other studies show a positive effect for vocational education that is organized on a sectoral or national level such as in Germany or Switzerland. A characteristic of these vocational education and training (VET) systems is a high level of standardization and regulation. In fact many elements of VET are regulated in national law, training ordinances and curricula, but firms nevertheless less still have a high flexibility when it comes to the organization of workplace training. In this paper we analyze how firms organize their workplace training, which training methods they use and which training methods they apply jointly. As each training method e.g. training during work or external courses, transfers a specific set of skills and knowledge to apprentices, we analyze how firms use training methods to promote their innovation activity. Our results show that there is a large variety in the organization of workplace training. In sum firms make use of the flexibility to design workplace training that fits their needs best. We conclude with implications for the design of VET systems and firms.

Keywords: Learning Modes, Innovation, Vocational Education, fsQCA, negative binomial regression.

1. Introduction

Within the ongoing debate about the advantages and disadvantages of vocational education and training in modern economies (e.g., Aghion, 2008; Krueger and Kumar, 2004a,b, Wolter et. al., 2006), a growing literature highlights the importance of vocational training for innovation in countries with a well-developed work-based training system (e.g. Germany and Switzerland) (Meuer et al. 2015). In these countries, apprenticeships are an important ingredient for the skill formation in many sectors of the economy. At the same time, firms in these economies are highly innovative (Frietsch et al., 2015).

Especially in Germany, apprenticeship training is highly regulated and the training curricula are legally binding for all firms offering training. However, while training curricula define a minimum standard for the training of a specific occupation, companies have considerable freedom in organizing their training internally. For example, companies can provide additional educational courses, hire external coaches or rather train apprentices "on the job". As a result, considerable heterogeneity exists with respect to the way companies organize learning processes. This paper exploits this heterogeneity to analyze the relation between different training methods and the knowledge they transfer to apprentices and the innovative outcomes in training firms.

Our theoretical approach builds on a classification of learning modes proposed by Jensen et al. (2007). We link these learning modes with different training methods in apprenticeship training and develop training models that cover different types of knowledge and influence the innovative output of firms. The approach distinguishes between two ideal modes of learning, the DUI (Doing, Learning and Interacting) mode and the STI (Science, Technology and Innovation) mode, which explain the relationship between different forms of knowledge (implicit and explicit) and innovative output of companies. To obtain expectations on the impact of apprenticeship training on innovation, we extend the model to incorporate the location of knowledge (internal vs. external to the company).

For the empirical analysis, we use primary German data from the 2012/2013 BIBB Cost-Benefit Survey (BIBB CBS). This data set contains rich firm-level information on both the different types of training and innovation outcomes in companies. Our empirical strategy consists of a combination of regression analysis and fsQCA (Fiss, 2007, 2011; Ragin, 2008), a set-theoretic method that allows the analysis of complex configurations of training types that explain the occurrence of an outcome, in our case innovation.

One important finding among a multitude of results is that a large group of firms reporting high innovation performance trains mainly on-the-job, with productive tasks on the skilled-worker level being a major ingredient for their training. These firms, however, combine productive tasks with external courses and supervision within the firm. With these and other results, the paper contributes to the understanding of the mechanisms driving the positive relationship between vocational training and innovation, which has been observed in the literature.

The paper is structured in the following way. In the subsequent Section 2, we briefly discuss the system of apprenticeship training in Germany and the motivation of firms to participate in training. Section 3 develops a model for analyzing the relationship between training modes and innovation. Section 4 discusses the data and the variables used in the empirical analysis. Section 5 describes or empirical approach, which involves two different stages. Section 6, we describe the results and in section 7, we discuss the empirical results in more depth. Finally, Section 8 provides some tentative conclusions.

2. The apprenticeship training system in Germany and firms' training motivation

In Germany, vocational education is the dominant pathway of youth on the road to employment. Within the vocational education system, apprenticeship training is the most common choice. Each year, approximately 550,000 school leavers (more than half of a cohort) enroll in an apprenticeship program (BIBB, 2013). Although German firms are not legally obliged to train apprentices, about 20 percent of all firms participate in the system (BIBB, 2013).

The German apprenticeship system is characterized by a high degree of standardization and coordination between stakeholders. About 350 different occupations are trained in the dual system (BIBB 2014). Apprenticeships last between 2 and 3.5 years, whereas most of the training (about 3 days of a working week) takes place in the firm. The remaining time (about 2 days in a working week) apprentices participate in vocational schooling. Thus, the firm is the dominant learning location in this 'dual' training system.

Of major importance are the training curricula (Ausbildungsordnungen), which define the skills and competencies that apprentices have to acquire during their training. Training curricula are occupation-specific and binding for all firms participating in the dual system. They are developed and modernized under a tripartite setting with employer associations, unions and the respective federal and state ministries participating in the regulation processes. While highly standardized and transparent, training curricula provide a broad framework for the skills and competencies of firm training. They define minimum standards, which are, at the end of the apprenticeship, tested in external examinations. As such, training curricula do not explicitly prescribe the training methods for the acquisition of the skills and competencies. Consequently, firms are free to develop their own training strategies, including the training method applied at the workplace. For example, firms may use part-time trainers instead of paying professional trainers to organize their training. They may use separate training centers, in which apprentices practice their skills or organize additional in-house classroom teaching to extend theoretical knowledge about the occupation. Firms may also train mainly on-the-job, providing the training through work experience in real-life production environments.

Theoretical and empirical literature has addressed the question why firms voluntarily participate in apprenticeship training. Considering that many firms bear training costs (Schönfeld et al. 2010), those firms would expect returns from training. Many of the studies argue that, upon retention of the apprentice, saved recruitment costs (Stevens, 1994), productivity gains (Acemoglu and Pischke, 1999) or high hiring and firing costs (Muehlemann et al. 2010) provide such returns. However, recent literature also discusses returns in the form of an increased innovative performance through training (e.g. Meuer et al., 2015; Rupietta and Backes-Gellner, 2015). Regarding the latter argument, this paper sheds light on the question, which modes of training organization are favorable for a high innovative performance in firms and thus increase incentives for providing training.

3. A Model of Linking Training to Innovation

Training methods in workplace training transfer different types of knowledge to the apprentices and to the firm. For example, on-the-job training transfers different knowledge to an apprentice than a theoretical course. We therefore distinguish four different types of knowledge that occur regularly in workplace training: explicit, implicit, external and internal knowledge. Firms can, when designing workplace training, select from a variety of training methods that are associated with the four types of knowledge. We therefore argue that the design of workplace training is an indicator for different types of knowledge that a firm expects an individual employee to process.

3.1. *Model of Learning an Innovation*

Jensen et al. (2007) distinguish between two ideal-type modes of learning and innovation: the science, technology and innovation (STI) mode and the doing, using and interacting (DUI) mode. The key characteristics of the DUI mode are implicit knowledge and experience-based know how. Knowledge in the DUI mode is often highly localized and context specific.

Knowledge sharing works via close informal interactions among employees. Companies can strengthen this mode by building organizational structures that facilitate communication among employees and coordinate interaction (Jensen et al. 2007). A mean to endow employees with know how is vocational education and training (Jensen et al. 2007). During training, apprentices learn how to perform occupation-specific tasks, terminology, and processes by closely interacting with their instructor.

The STI mode describes explicit knowledge and understanding of mainly general problems. The STI mode also covers context-specific local knowledge that is necessary to apply codified knowledge to specific problems. Knowledge transfer in the STI mode works via the dissemination of general knowledge in articles, textbooks and patents. Scientists typically obtain general knowledge from their university education. Their ability to apply this general knowledge to specific-context is a result of experience in a certain area.

Both modes of learning operate with specific types of knowledge. Employees who operate with these types of knowledge completed different types of education. The DUI mode requires workers with specific and experience-based know how that Jensen et al. (2007) attribute to vocational education and training. The STI mode operates with scientific knowledge that is general and explicit. However, some education programs combine both experience-based know how and general knowledge and thus provide firms with employees that can bridge both modes of learning.

3.2. *Model extension: External and internal knowledge sources*

The original model by Jensen et al. (2007) distinguishes between implicit knowledge and explicit knowledge, but is less specific on the location of a knowledge source from a firm's perspective. Knowledge can be either internal or external. Internal knowledge covers the knowledge of a firm's employees but also manuals, handbooks, own patents, process descriptions and routines. External knowledge covers knowledge that are located outside a firm’s boundaries and covers knowledge from a firm’s stakeholders but also publically available knowledge.

Researchers study internal and external knowledge often in combination and argue that these two types of knowledge depend on each other to generate innovations. Cohen and Levinthal (1990) argue that firms require a critical amount of internal knowledge and R&D to integrate external knowledge in their innovation process. The amount of internal knowledge determines how much external knowledge a firm can absorb in order to use it productively. The internal knowledge thus helps building a firm’s capability to use external knowledge. Cohen and Levinthal (1990) call this capability ‘absorptive capacity’.

To generate innovations a combination of both internal and external knowledge is beneficial. If a firm only relies on internal knowledge, it might have enough knowledge to have a high absorptive capacity but does not make use of it and thereby misses ongoing technological developments or the needs of their stakeholders. If a firm relies on external knowledge without focusing on internal knowledge it might miss essential components of the external knowledge because it lacks absorptive capacity. Thus, firms have to focus on both internal and external knowledge sources in order to generate innovations.

We extend the model by Jensen et al. (2007) by linking the innovation modes to the location of knowledge sources and theorize on synergies between different types of knowledge. Both the DUI/ STI mode and external/ internal knowledge entail synergies. For example, Jensen et al. (2007) argue that a combination of DUI/STI has the potential for a higher innovation performance than a single ideal type. They show this pattern in their empirical analysis where they use data from Danish companies. They conclude that “It is the firm that combines a strong version of the STI mode with a strong version of the DUI mode that excels in product innovation” (Jensen et al., 2007, 685). Thus, a combination of both ideal types enhances a firm’s innovation performance. Somewhat similar to synergies between the DUI and the STI mode, the literature on absorptive capacity argues that internal knowledge helps absorbing external knowledge (Cohen and Levinthal, 1990).

Figure 1: Learning modes and location of knowledge sources

External DUI Mode	External STI Mode
Internal DUI Mode	Internal STI Mode

Following our theoretical argumentation, we can define four modes on innovation and learning that have their own distinct properties but are linked to each other via synergies. Figure 1 shows the four modes of innovation and learning. The internal DUI mode operates with internal knowledge that stems from experiences-based know-how and informal learning. Similarly, the external DUI mode that works with external knowledge that stems from experiences-based know-how and informal learning. The internal STI mode operates with codified knowledge that originates from the firm, while the external STI mode operates with codified knowledge that originates from outside of a firm's boundaries.

3.3. *Classification of training methods*

We use the newly defined internal/external DUI and internal/external STI modes of learning and innovation to classify training methods in workplace training. We define all training methods that rely more on practical demonstrations and learning by doing as part of the DUI mode. Conversely, we locate all theoretical forms of instruction and learning with textbooks, handbooks or other written material to the STI mode. Workplace training covers several training methods that fit into these two modes. Supervised instruction at the production line is one perfect example of the DUI mode. In this training method, the apprentice tries to perform the tasks in the same way as the instructor does, learns the sequencing of tasks and mimics the behavior and the language of the instructor. On the contrary, formal courses with written textbooks that contain theory and explanations are a good example for the STI mode. This written communication of knowledge, which provides an explanation of a task rather than the learning of the actual way of performing it, is characteristic for the STI mode. As firms can apply multiple training methods, their training can be either purely DUI or STI mode or is located somewhere in between both ideal type modes.

We begin explaining how training methods influence innovation by building four categories according to the type of knowledge (implicit/DUI mode vs. explicit/STI mode) and the location of knowledge (internal vs. external). In Figure 1, we show these four categories. The lower left corner of Figure 1 shows the internal DUI mode, a combination of internal and implicit knowledge. This might be the typical way of thinking about apprenticeship training. An apprentice learns implicit knowledge such as occupation-specific tasks, language, and behavior trough close interactions with his or her supervisor. This knowledge does not come from textbooks but rather from learning-by-doing and learning-by-imitating. Examples for such training methods are training at the production line with supervision by an instructor or a training workshop.

The upper left corner contains a category that combines external and implicit knowledge. Training methods that belong to this category also rely on a close interaction between apprentice and instructor, like in the internal DUI mode. The instructor, however, brings new knowledge into the firm, if she is external. Examples for the external DUI mode could be instructors from a machine producer that sells new machines to the company. Apprentices then learn how to operate a new technology without getting a deeper theoretical introduction in this technology. From this category, we expect an impact on innovation, because new knowledge that might drastically change processes and products enters the firm. However, its diffusion speed is rather limited due to the direct interaction between instructor and the supervisor.

The lower right side of Figure 1 summarizes training methods that transfer explicit knowledge that has its origin in the firm. In such courses, the learning-by-doing is not important. However, gaining an in-depth understanding of why certain tasks should be performed or why they should be performed in a specific order is more important. Knowledge is transferred between instructor and apprentices in a written and codified form. Examples for this internal STI mode are company courses on production practices that have been summarized in textbooks or handbooks.

3.4. *From innovation modes and training methods to configurational training models*

We derive training models that are linked to the four innovation modes and consist of different training methods. These training models show how firms train to obtain high innovation performance.

We develop three models of training, which correspond to the theoretical framework discussed above. Training during work has a strong focus on experience-based know-how and informal learning. Traditionally, an apprentice learns on the job with supervision by an instructor. This on-the –job training enables apprentices to apply theoretical knowledge in the production process and to obtain direct feedback from the instructor. The close collaboration with the instructor links the apprentices to a broader network of professionals working in the same occupation. By being part of this network apprentices can improve informal learning. This training method is essential and resembles the core of workplace training. We thus expect that training during work is part of all successful combinations of training types as it lays the foundation for informal learning and internal knowledge sharing. We therefore call this mode the ‘basic training model’.

We now use the synergies between our innovation modes to derive our second and third training model. To incorporate external knowledge in the innovation process, firms require a substantial amount of internal knowledge in order to absorb the external knowledge (Cohen and Levinthal, 1990). In the context of workplace training, we expect a similar pattern. Apprentices who gain access to external knowledge during workplace training need to have a solid foundation of internal knowledge. Without internal knowledge apprentices cannot link external knowledge to the production processes of their training firm. We call this combination the ‘knowledge absorption model’ of training.

Jensen at el. (2007) argue that synergies exist between the DUI and the STI mode of innovation. More explicitly, they argue that prior knowledge on a topic facilitates the learning of explicit knowledge. Workplace training gives firms the opportunity to illustrate complex theoretical topics with practical examples and thus helps to build implicit knowledge that can precede the learning of more complex explicit knowledge. We therefore call the combination of implicit and explicit learning the ‘knowledge formalization model’ of training.

Table 1: Three training models for workplace training

Training model	**Basic training model**	**Knowledge absorption model**	**Knowledge formalization model**
Knowledge type			
Explicit	No	No	Yes
Implicit	Yes	Yes	Yes
External	No	Yes	No
Internal	Yes	Yes	Yes

Table 1 summarizes the three training models. They contain predications that we expect to occur in configurations of training methods. They are thus helpful for relating single empirically identified configurations back to theory. We use these models to elaborate the internal structure of configurations further in the discussion.

4. Data and variables

This section first describes the data source used in this paper. It then describes the variables for the empirical analysis.

4.1. Data source

The data for our empirical analysis stems from the most recent firm-level survey on the costs and the benefits of apprenticeship training (CBS). The survey was conducted by the Federal Institute for Vocational Education and Training (BIBB) for the training year 2012/2013 and gathered data for 3000 firms training in more than 200 of the in Germany registered training occupations. The field work was organized by *infas* institute that conducted personal computer-assisted interviewing (CAPI) in the surveyed firms. The sample of firms was drawn from the register at the Federal Employment Agency (BA), where all firms with at least one employee subject to social security payments are registered.

The BIBB CBS of 2012/2013 is the latest wave of a series of repeated cross-section surveys, which were first conducted in the 1970s.

4.2. Selecting relevant variables

For the purpose of this study, we included a module on the innovative activities of training firms in the survey of 2012/2013 that we implemented on top of the regular questionnaire program. The aim of the module was to capture information about the existence and volume of incremental innovation in training firms. The interviewers inquired about the number of improved products and production technologies. The implementation of innovative outcome variables in the questionnaire was based on Hollenstein (2003), who implemented incremental innovation as the number of better products or processes. The reason for focusing on incremental innovation is that this type of innovation mainly results from existing knowledge sources complemented by new knowledge inflows, while radical innovation mainly results from new knowledge inflows that a firm absorbs. Workplace training covers predominantly existing knowledge in firms and therefore incremental innovation is an appropriate outcome for our study.

Apart from the innovation indicators, the data set contains a large number of variables concerning the training organization in the firm. We use these variables to identify the learning modes of external and internal DUI and STI. Training methods that rely on internal and implicit knowledge and mainly consists of learning-by-doing represent the internal DUI mode. To represent this mode in our empirical analysis we use the employment of professional trainers, the availability of a training center, a high level of skilled productive work and a high level of training during work. For the internal STI mode, we use a training method that mainly transfers explicit and codified internal knowledge to apprentices. This mode does not focus on learning-by-doing but by a theoretical education and a deeper understanding of why something works. In of analysis the use of internal courses represent this mode. The external DUI mode is similar to the internal on but contains only external knowledge. We measure this mode by the involvement of external trainers in workplace training. These trainers have knowledge that originate from other firms and provide learning-by-doing. Similarly, the external STI mode works like the internal STI mode but operates with external knowledge. External theoretical courses represent this mode.

For the initial regression analysis, we drop 597 from the initial 3028 training firms due to missing information on one of the dependent or independent variables. We remove another 742 due to missing values on the investment measure, which enters the regressions as an important independent variable. For both the regression analysis and the qualitative comparative analysis, we use 1689 observations.

5. Empirical strategy: A two-stage approach

Our empirical analysis is based on a two-stage procedure that combines regression analysis with fuzzy set qualitative comparative analysis (fsQCA) (Jackson and Ni, 2013). In the first stage, we use negative binomial regression models to calculate the unexplained part of innovation, which is used as outcome variable for the second stage. In the second stage, we use fsQCA, a method that is able to identify combinations of variables that explain an outcome. The strength of this method is the identification of multiple combinations that are equally effective in generating the outcome. In the context of this study fsQCA identifies multiple equally effective ways of organizing workplace training to generate innovations. By using the unexplained part of a negative binomial model as an outcome for the fsQCA, we overcome the limited number of variables that a standard QCA can handle.

5.1. The first stage: Negative binomial regressions

For the first step of the analysis, we estimate negative binomial regression models[1], which we regress our outcome variables discussed above (i.e. the number of new or improved products and processes) on a set of explanatory variables. Due to the existence of multiple determinants for innovation, we construct a series of variables to be used as explanatory variables in our models. The first set of variables addresses both economic sector and regional discrepancies in the existence of innovative activities at the firm level. We therefore include a set of economic sector dummies (19 categories based on the NACE Rev. 2) and a regional dummy (East-West Germany) in the models. We further include controls for the qualification structure in the firm (i.e. the share of low-, medium- and high-qualified employees). The models further contain the total sum of firm investment (in Euro) in the reference year.

[1] We prefer the negative binomial regression over the standard Poisson model due to the existence of overdispersion (unconditional and conditional variance is considerably larger than the means). The choice is supported by a Likelihood-ratio test of alpha=0, which yields a large chi-squared value. We also refrain from the use of a zero-inflated regression model, since the zeros in our outcome data are “true” zeros (e.g. zero new products truly means that there has been no new product in the firm).

Finally, the models include a dummy on whether the firm cooperates with other firms to control for external knowledge sources driving innovation.

Because firm-size is a crucial determinant for the incidence and number of innovations, we use the (continuous) number of employees in a firm as an “exposure variable” in the negative binomial regressions. We then calculate the unexplained part of the Negative Binomial model, arguing that that none of the included determinants drives our results in the second step of the analysis (see Jackson and Ni, 2013) and use it as an outcome in the second step, the fsQCA.

5.2. The second stage: Qualitative Comparative Analysis (QCA)

In the second step of our analysis, we use fsQCA to identify combinations of training practices that firms use. FsQCA entails two important features of our model. First, it allows us to incorporate equifinality in our analyses (Fiss 2007). In our theoretical approach, we assume that firms use different ways to organize their workplace training in order to generate innovation. FsQCA is particularly suited for such a setting because it can identify multiple ways of organizing workplace training. The resulting configurations are all equally effective in producing innovation.

Second, we assume that some ways of organizing workplace training in VET can support innovation. However, we do not assume that the exact opposite of successful ways of organizing affects innovation negatively. This assumption originates from the notion that VET in general supports innovation activities of firms (Rupietta and Backes-Gellner 2015, Meuer et al. 2015). FsQCA can deal with such situations of causal asymmetry where the presence of a supporting factor has a positive impact of an outcome whereas the absence of a factor not necessarily has a negative one. More standard methods, such as regression analysis, have no straightforward solutions to incorporate situations of causal asymmetry because their basic assumptions build on symmetric causal relationships. Thus fsQCA works in line with the properties of our theoretical model in is therefore well-suited for our empirical analyses.

FsQCA is a set-theoretic method that uses Boolean algebra to identify combinations of variables that are associated with an outcome. The typical fsQCA analysis consists of three analytic steps: calibration, truth table analysis and Boolean minimization. In the first step, the calibration, all variables are transformed into sets. This step is necessary because fsQCA is a set-theoretic method and can only operate with this kind of information. Fuzzy sets range from 0 to 1 whereas 1 indicates a full set membership and 0 a non-membership in a set. The value 0.5 indicates the point of maximum ambiguity between set membership and non-membership. Whenever the set membership exceeds 0.5 fsQCA calls a condition “present”, when it is below 0.5 fsQCA calls it “absent”. In this paper, we apply a calibration method - indirect calibration - that assigns set membership values according to three anchor points. These anchor points define the full membership, the non-membership and the point of maximum ambiguity. Based on these points a logarithmic function calculates the membership of each observation in a set.

The second step in fsQCA is the truth table analysis. A truth table contains all combinations of present and absent conditions. The size of a truth table is determined by the number of conditions *k* that are in the model. Thus, a truth table contains 2^k rows, because a condition has two states (present or absent). Each truth table row represents a configuration of conditions. These configurations group observations that are equal in terms of conditions and outcome. The truth table thus shows how many observations belong to a configuration and how strong this configuration is associated with the outcome.

The third step in the fsQCA is Boolean minimization. Although a truth table reduces the complexity of the information that the data contain, some complexity still remains. The goal of the Boolean minimization is to identify only those configurations that are either associated with the presence or the absence of the outcome. Moreover it shortens the length of a configuration and tries to identity the most parsimonious way to express configurations. To achieve this goal, it compares configurations across truth table rows and reduces them by applying Mill's method of difference: If two configurations share the same outcome but differ only in a single condition, this condition is irrelevant for generating the outcome and can be removed from the configuration. Following this logic, the remaining configuration is a product of comparing truth table rows and deleting those conditions that do not matter for generating the outcome. Researchers have implemented this procedure in several software applications, such as fsQCA (a correspondent software developed by Ragin and Davey, 2014), TOSMANA (by Cronqvist, 2011) and R (package written by Dusa and Thiem, 2013).

6. Results

We present the results of the second of our two analytical steps – the fsQCA – and describe the organization of workplace training and its influence on innovation in the following subsections. We do not elaborate on the description of the results from the first step (i.e. the negative binomial regression), because we only use it to generate a more precise outcome. For completeness, however, we show the regression results from the first step in Table A1 in the appendix.

We present the results of the fsQCA analysis according to Ragin and Fiss (2008) as a configuration chart. The tables presented in this section contain a configuration chart that lists all configurations of workplace training that lead to high incremental innovation. The first column on the left lists all explanatory variables, i.e. training methods that firms use during workplace training. Each of the following columns depicts one combination of training methods that firms use to be highly innovative. A configuration consists of larger and smaller circles. The large circles indicate the core elements of a configuration. The small circles indicate the peripheral or contributing elements; those that support the core elements of a configuration. Circles that are completely filled indicate the presence of an explanatory variable. Crossed circles indicate the absence of an explanatory variable. Empty cells mean that the presence or the absence of the explanatory variable does not matter for explaining the outcome.

The tables in the result section refer to different configuration of workplace training, which are associated with high innovation performance in Germany. These configurations fulfill the two standard criteria for fsQCA solutions: the overall solution consistency and the overall solution coverage. The overall solution consistency is 0.83, a value that exceeds the recommended consistency threshold of 0.8 (Fiss, 2011, Ragin and Fiss 2008). The overall solution coverage is at 0.31, a value that lays within the range of similar QCA studies (Fiss 2011 reports 0.37, Misangyi and Acharya, 2014, report 0.16 and Meuer et al., 2015 report 0.19). The respective solution consistency and coverage values are displayed for each of the configuration results.

We first discuss the results for high incremental product innovation, starting with the configuration representing the most of the firms in the sample (i.e. having the highest coverage, as shown in the respective tables). We then show descriptive information about the distribution of the firms in the specific configurations across structural variables (industry, occupation and firm size) to check on concentrations of certain training methods in the respective categories. Finally, we provide results of an analysis using low instead of high incremental innovation in firms to address the issue of causal asymmetries.

6.1. High incremental product innovation

In Table 2, the first configuration is characterized by the presence of skilled productive work and training during work. Further, external courses are used in this combination of training modes. Internal courses, in contrast, are absent, while the other training modes (professional trainers, training center and external trainers) are ‘don’t care’ conditions and thus can be either absent or present. This configuration combines different knowledge sources. The intense use of internal implicit knowledge (skilled productive work and training during work) is accompanied by external explicit knowledge gained from external courses. The high raw (0.17) and unique (0.16) coverage indicates that this form of training organization is used relatively often among firms reporting incremental product innovation.

The second configuration is characterized by the absence of a training center, a high level or skilled productive work, internal courses and external courses. Present is a high level of training during work. The absence of use of external trainer is a contributing condition. This configuration mainly relies on internal implicit knowledge. Firms applying this configuration strongly focus on learning-by-doing and a strong collaboration of apprentices and supervisor. Apprentices gain practical skills and learn from their instructors. Moreover, they also learn how to implement theoretical knowledge that they learn in vocational schools in practice. This configuration comes close to what Jensen et al. (2007) describe as the DUI mode of learning, as it mainly contains experience-based know-how, close interaction between supervisors and apprentices and implicit knowledge. Like the first configuration, this type of training organization is used relatively often, having a raw and unique coverage of 0.1.

The third configuration in Table 2 includes training during work, external trainers and the use of internal courses as necessary conditions for incremental product innovation in firms. It combines the knowledge sources internal implicit knowledge, internal explicit knowledge and external implicit knowledge. This configuration is obviously not a standard model for organizing workplace training. A moderate number of firms (29) organize their workplace training this way. It seems that firms, which apply this configuration, provide a thorough workplace training that diffuses internal knowledge quickly and integrates new external knowledge.

The fourth configuration entails an internal training center and a high level of skilled productive work. Contributing conditions are the presence of a high level of training during work and the absence of external trainers. This configuration relies mainly on internal knowledge sources and uses only learning techniques that foster learning-by-doing. The two core conditions indicate that firms that use this configuration prepare their apprentices thoroughly for manual tasks. In the first 1-2 year of their apprenticeship, apprentices learn manual tasks, like welding or operating machines, apart from the production line. With a certain level of mastery in these skills, apprentices work like regular employees and produce goods that the company can sell to customers. To apply this configuration in practice, firms have to operate a training center. Only a few firms that have large economies of scale can make these investments to train their apprentices that way. The moderate number of firms applying this configuration (25) supports this notion.

The fifth and last configuration involves training during work, internal courses and the absence of a high level of skilled productive work and external courses as core conditions. The presence of a training center is a contributing condition. This configuration relies on internal knowledge only but contains both implicit and explicit knowledge. Firms that use this configuration do both they invest in a thorough training of manual skills and design internal courses to foster theoretical education and quick knowledge diffusion. Apprentices learn these different types of knowledge and combine them during their productive work.

We compare the five configuration to the three training modes (basic training mode, knowledge absorption mode, and knowledge formalization mode) to analyze the internal mechanism of each configuration. The basic training mode occurs in the second and fourth configuration. This configuration covers with 118 firms a large number of highly successful innovators thereby highlighting the importance of the basic training mode for incremental innovation. The knowledge absorption mode occurs in the first and third configuration. This mode occurs in 198 firms. The integration of external knowledge sources generates an inflow of relevant knowledge that complements a firm's existing knowledge and facilitates the improvement of their existing products. The knowledge formalization mode occurs in configuration one, three, and five, covering 200 firms. The codification of existing knowledge allows a faster diffusion of knowledge within the firm and thereby contributes to the development of incremental innovations. The first and the third configuration shows that firms combine the knowledge absorption mode and the knowledge formalization mode. In sum the results show that the training modes that we derived theoretically occur in our empirical analysis.

Table 2: Configurations for achieving high incremental product innovation

Configurations for achieving high incremental product innovation					
			Solution		
	1	**2**	**3**	**4**	**5**
Professional trainers					
Training centre		⨂		●	•
Skilled productive work	●	⨂	⨂	●	⨂
Training during work	●	●	●	•	●
External trainers		⊗	●	⊗	
Internal courses	⨂	⨂	●		●
External courses	●	⨂			⨂
Consistency	0.85	0.82	0.78	0.78	0.79
Raw coverage	0.17	0.10	0.03	0.03	0.01
Unique coverage	0.16	0.10	0.03	0.01	0.00
Overall solution consistency		**0.83**			
Overall solution coverage		**0.31**			
No. of firms	169	93	29	25	6

6.2 How prevalent are the configurations with respect to industry, occupation or firm size?

While the configurations contain detailed information on how firms organize their training to be innovative, they may apply only to specific firms (e.g., firms belonging to one industry). To analyze whether the configurations cover the entire firm population or are only relevant for specific firms, we add descriptive information on the firms that belong to a configuration. For each configuration we obtain the average firm size, the distribution of size classes and the sectoral distribution. We summarize the results in Table 3.

The results in Table 3 show how firms differ across configurations. We obtain a strong difference in the average firm size in each configuration. While configurations one to three cover firms that have on average between 39 and 91 employees, the average firm size for configuration four is 286 employees and only 6 employees for configuration five. When we combine these results with the results on the distribution of size classes, we can show that configurations one to four cover firms from several size classes ranging from micro enterprises (5-9 employees) to very large companies (1000 and more employees). Thus it seems that firms of very different size can apply these configurations successfully. Only configuration five cover firms that are not larger than 49 employees. Overall our results show that the applicability of the configurations (except configuration five) are not restricted by firm size.

We also analyze whether the configuration are specific for an industry. The results show that configurations one and two cover firms from several industries. These results do not indicate any industrial specificity for configurations one and two. Configurations three to five cover much less firms (max. 29). Configuration three also covers firms from several industries and therefore has a low specificity. Configuration four mainly contains firms from manufacturing, construction, other service activities, and wholesale, retail trade, and repair of motor vehicles and motorcycles. Thus this configuration appears to be specific for these four industries. Configuration five covers only six companies of which three provide services belonging to human health and social work activities. In sum the configurations (except configuration four) are not specific to an industry. The configurations offer generic combinations of training methods that firms from different industries can implement successfully.

Table 3: Descriptive statistics for configurations that achieve high incremental product innovation

Configurations for achieving high incremental product innovation

	Solution				
	1	2	3	4	5
No. of firms	169	93	29	25	6
Firm size	47.69	39.19	90.83	286.48	6.17
Size classes					
5-9 employees	70	39	6	13	5
10-49 employees	69	41	15	5	1
50-99 employees	15	5	4	3	0
100-249 employees	6	6	1	0	0
250-499 employees	5	0	0	1	0
500-999 employees	1	1	3	1	0
1000+ employees	2	1	0	2	0
Industry					
Agriculture, forestry and fishing	0.02	0.03	0.00	0.04	0.00
Mining and quarrying	0.00	0.00	0.00	0.00	0.00
Manufacturing	0.12	0.12	0.10	0.28	0.00
Electricity, gas, steam and air conditioning supply	0.00	0.00	0.03	0.04	0.00
Water supply; sewerage, waste management and remediation activities	0.02	0.00	0.00	0.00	0.00
Construction	0.18	0.11	0.14	0.24	0.17
Wholesale and retail trade; repair of motor vehicles and motorcycles	0.18	0.15	0.17	0.12	0.17
Transportation and storage	0.02	0.03	0.14	0.00	0.00
Accomodation and food service activities	0.04	0.11	0.07	0.00	0.00
Information and communication	0.01	0.05	0.00	0.00	0.00
Financial and insurance activities	0.01	0.01	0.07	0.00	0.00
Real estate activities	0.02	0.02	0.00	0.00	0.00
Professional, scientific and technical activities	0.11	0.12	0.00	0.00	0.00
Administrative and support service activities	0.06	0.05	0.07	0.04	0.00
Public administration and defence; compulsory social security	0.01	0.00	0.00	0.04	0.00
Education	0.01	0.03	0.03	0.00	0.00
Human health and social work activities	0.08	0.12	0.10	0.04	0.50
Arts, entertainment and recreation	0.02	0.00	0.00	0.00	0.00
Other service activities	0.08	0.04	0.07	0.16	0.16
Activities of households as employers; undifferentiated goods- and services producing activities of households for own use	0.00	0.00	0.00	0.00	0.00
Activities of extraterritorial organizations and bodies	0.00	0.00	0.00	0.00	0.00
Training costs					
Average gross training costs	19588.03	20011.26	24779.36	20506.73	21341.68
Average training benefits	13745.36	13047.36	12664.72	11989.85	9482.17
Average net training costs	5842.67	6963.90	12111.64	8516.87	11859.50

6.3 Causal asymmetry: What explains low incremental product innovation in firms?

In this section, we take a closer look at the possibility of certain combinations of training methods explaining a low incremental product innovation. The intention is, to understand whether certain (combinations of) training methods might be counterproductive to the innovativeness of firms. We apply the same calculation procedure as in 6.1, only that the outcome is a “low” instead of a “high” degree of product innovation.

Table 4 illustrates that the configurations for low incremental innovation have a very low coverage and thus concern only a very limited number of firms. For those few firms, the results imply that professional trainers in combination with various other training components (such as training during work or external trainers) seem to be counterproductive for innovative outcomes in the workplace. Further, the combination of separate training centers and internal courses are related to a low innovation performance of firms. In four configurations we find that the basic training model i.e. a strong focus on training during work, is missing. The basic training model is the key ingredient of all configurations that generate high innovation performance.

Table 4: Configurations for achieving low incremental product innovation

Configurations for achieving low incremental product innovation					
	Solution				
	1	**2**	**3**	**4**	**5**
Professional trainers		⊗	●	●	●
Training centre	●	●	⨂	⊗	⊗
Skilled productive work	⊗		⊗	●	⊗
Training during work	⨂	⨂	⊗	⊗	●
External trainers	⨂	⨂	●	⊗	⊗
Internal courses	●	●	•	●	•
External courses	⨂	⨂	•	⊗	⨂
Consistency	0.88	0.86	0.83	0.83	0.85
Raw coverage	0.01	0.01	0.01	0.01	0.004
Unique coverage	0.01	0.004	0.01	0.004	0.003
Overall solution consistency		**0.87**			
Overall solution coverage		**0.03**			
No. of firms	9	7	6	5	3

Nevertheless we also find one of the training modes in a configuration that generates low incremental innovation performance. Configuration 5 contains the knowledge formalization model. Although this configuration is similar to a configuration that generates high incremental innovation performance, the internal mechanisms of these two configurations are different. The configuration that generates high incremental innovation performance connects explicit knowledge from internal courses with implicit knowledge from workplace training and connects these two types of knowledge in a training center. The training center allows apprentices to practice new working techniques and gives them time to transfer explicit knowledge into implicit knowledge. The configuration that generates low incremental innovation performance does not rely on training centers but focusses on professional trainers. Thus a learning environment that gives apprentices time to transfer explicit into implicit knowledge is missing in this configuration. To support incremental innovation the knowledge formalization mode might require training methods that help apprentices to bridge implicit and explicit knowledge.

In sum the results for low incremental innovation performance show that the identified configurations lack empirical relevance as the low coverage score indicates. Four out of five configuration lack the basic training mode, an important ingredient of configurations that lead to high innovation performance. One configuration seems to apply the knowledge formalization mode in a suboptimal way and does not bridge implicit an explicit knowledge. Overall the results of table 2 and table 4 indicate that VET with its various ways of organizing workplace training is a factor that contributes strongly to a firm's high incremental innovation performance and does not impede innovation.

7. Discussion

Overall, our results show that firms organize their workplace training in several distinct ways. Some firms combine only training methods that transfer implicit and internal knowledge to apprentices (the basic training model) to obtain incremental innovations. Internal and implicit knowledge is the key component of every configuration that explains incremental innovation. Some firms add other knowledge sources to the internal and implicit knowledge. By combining other knowledge sources such as explicit and external knowledge to the basic training model firms apply the knowledge acquisition mode, the knowledge formalization model, or a combination of both.

The above findings have at least three implications: First, Jensen et al. (2007) define the two modes of learning and innovation (STI mode and DUI mode) as two contrasts. While the STI mode operates with explicit and scientific knowledge, the DUI mode cover interactions, implicit and tacit knowledge and learning by doing. Although these modes are distinct, Jensen et al. (2007) highlight that firms can combine these modes and that a combination might lead to superior innovations outcomes.

In this paper, we suggest an extension to the model proposed by Jensen et al. (2007). In our extension we add the location of the knowledge source (internal or external from a firm's perspective) to the original model. With this extension we define training models that are closely linked to a firm's innovation process. For example the inclusion of external knowledge during workplace training prepares apprentices for an innovation process that relies on several external knowledge sources (e.g., customer, supplier, and competitors). Such an open innovation process requires employees who are able to absorb and apply external knowledge. Thus the knowledge absorption model of training might facilitate the application of open innovation processes in firms.

Second, our study adds to the discussion on the suitability of vocational education for promoting innovation and growth. Several studies argue that vocational education is too narrow and operates with outdated technologies and thus cannot have a positive impact on innovation of firms and on the growth of countries. With our study, we establish a further link between vocational education and innovation. Our results show that not vocational training itself but the organization of training matters for innovation. Workplace training allows firms to connect different unconnected knowledge sources. This connection of unconnected knowledge has the potential for the generation of new knowledge that generated innovation (Kogut and Zander, 2004).

Finally, we show that a standardized vocational education and training system is flexible enough to allow multiple forms of training organization. While the training content is defined in curricula that guarantee minimum training standard, firms are free to organize workplace training in their own way. This makes the participation in the training system even more valuable because firms receive a knowledge inflow from the curriculum but are free to decide how they organize training to extract the most valuable knowledge. In the context of the ongoing discussion about the costs and benefits of training, many studies emphasize recruitment benefits and productivity effects (e.g. Acemoglu and Pischke, 1999 or Muehlemann et al. 2010). This paper shows that several models of training foster the innovative capacity of firms. Although not easily quantified in monetary terms, the benefits of an increased innovative potential may be an additional factor in firms' training investment decision.

8. Conclusion

Building on a theoretical model of learning, this paper analyzed how firms can organize apprenticeship training to increase their innovative performance. We showed that several of the successful ways to organize workplace training involve a combination of different knowledge sources. As a rule of thumb, training methods that are closely tied to the real production environment in a firm are the base ingredient for incremental product innovation. We describe this combination of implicit and internal knowledge the 'basic training model'. In addition, we find that a 'knowledge absorption model' (combining internal and external learning) and ‘knowledge formalization model’ (combining implicit and explicit learning) are promising pathways to generate innovation in firms.

The results of this paper have implications for theory, practice, and policy. First, the findings show that extending a two-dimensional approach of learning may be beneficial to explain the relationship between forms of knowledge acquisition and innovation on the firm level. While we provided empirical evidence for a specific form of training (apprenticeships), the framework could be useful also for other fields of education and training.

Second, the results imply that firms can take advantage of the flexibility of the system to experiment with different training methods and thus could systematically optimize the innovation outcome of apprenticeship training over time. Although innovation can be an intended training outcome of firms, others might not be aware of this potential benefit and could tailor their respective HRM strategies accordingly.

Third, and related to the second point, the findings imply that the currently existing degree of flexibility provides incentives for firms to invest in the training of youth. Although the standardization of curricula and training quality is desirable for keeping the system attractive for students, policy measures that interfere with firms’ freedom to organize training individually could be counterproductive.

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Appendix

Table A1: Negative binomial regressions: Product innovation (Improved products)

	Improved products		New products	
	Coef.	Std. Err.	Coef.	Std. Err.
Economic Sector (ref. Wholesale and retail trade)				
Agriculture, forestry and fishing	-0.99	0.42	-2.05	0.44
Mining and quarrying	-2.66	1.83	-2.90	1.90
Manufacturing	0.47	0.27	-0.98	0.27
Electricity, gas, steam and air conditioning supply	-1.95	0.64	-2.55	0.65
Water supply; sewerage, waste management and remediation activities	-5.09	1.03	-6.24	1.09
Construction	-0.72	0.25	-1.52	0.26
Transportation and storage	-2.39	0.38	-3.40	0.39
Accommodation and food service activities	-0.77	0.31	-0.97	0.31
Information and communication	0.49	0.35	-0.27	0.36
Financial and insurance activities	1.14	0.46	-0.58	0.49
Real estate activities	-1.42	0.51	-2.07	0.53
Professional, scientific and technical activities	-0.82	0.29	-1.18	0.30
Administrative and support service activities	-0.94	0.29	-0.98	0.30
Public administration and defence; compulsory social security	-3.54	0.40	-4.42	0.43
Education	-2.22	0.63	-2.34	0.65
Human health and social work activities	-0.40	0.27	-0.66	0.30
Arts, entertainment and recreation	-1.62	0.81	-1.20	0.77
Other service activities	-0.61	0.29	-0.34	0.29
Region (ref. East Germany)				
West Germany	0.56	0.18	1.31	0.18
Qualification structure (ref. Share of highly qualified workers (Uni)				
Share of unskilled workers	-0.48	0.49	0.68	0.49
Share of medium qualified workers	-0.80	0.29	-0.22	0.30
Share of highly qualified workers (VOC)	-0.46	0.38	0.46	0.42
Total investment last year	0.00	0.00	0.00	0.00
Cooperation with other firms	0.64	0.16	0.75	0.18
Constant	0.27	0.31	-0.28	0.31
ln(Number of employees in firm)	1.00	(exposure)	1.00	(exposure)
Ln(alph)	1.83	0.04	1.92	0.04
Alpha	6.26	0.24	6.81	0.26

Observations: 1689

References

Acemoglu, D., Pischke, J.-S. 1999. The Structure of Wages and Investment in General Training. Journal of Political Economy 107, 539-572.

Aghion, Philippe. 2008. Higher Education and Innovation. Perspektiven der Wirtschaftspolitik 9, Special Issue:28–45.

Becker, G. S., 1962. Investment in human capital: a theoretical analysis. Journal of Political Economy 70, 9–49.

Becker, G. S., 1964. Human Capital. A Theoretical and Empirical Analysis with Special Reference to Education. Chicago, London.

Beicht, U., Walden, G., Herget, H., 2004. Kosten und Nutzen der betrieblichen Berufsausbildung in Deutschland. Bundesinstitut für Berufsbildung. Berichte zur beruflichen Bildung, Heft 264. Bertelsmann, Bielefeld.

BIBB Bundesinstitut für Berufsbildung, 2013. Datenreport zum Berufsbildungsbericht 2013. Bonn.

BIBB Bundesinstitut für Berufsbildung 2014. Die anerkannten Ausbildungsberufe 2014. Bertelsmann, Bielefeld.

Cohen, W. M., Levinthal, D. A., 1990. Absorptive Capacity: A new Perspective on Learning and Innovation. Administrative Science Quarterly 35, 128-1S2

Cronqvist, L., 2011. Tosmana: Tool for Small-N Analysis, Version 1.3.2.0. Trier: University of Trier.

Duşa, A., Thiem A., 2013. QCA: Qualitative Comparative Analysis. R package version 1.0-5.

Fiss, P., 2007. A set-theoretic approach to organizational configurations. Academy of Management Review 32, 1180-1198.

Fiss, P., 2011. Building better causal theories: a fuzzy set approach to typologies in organization research. Academy of Management Journal 54, 393-420.

Frietsch, R., Rammer, C., Schubert, T., Som, O., Beise-Zee, M., Spielkam, A., 2015. Innovationsindikator. acatech / Bundesverband der Deutschen Industrie e.V. (BDI). Berlin.

Hollenstein, H., 2003. Innovation modes in the Swiss service sector: a cluster analysis based on firm-level data. Research Policy 32, 845-863.

Jackson, G., Ni, N. 2013. Understanding complementarities as organizational configurations: using set theoretical methods. In: Fiss, Peer C., Cambré, Bart, Marx, Axel (EDS.), Configurational Theory and Methods in Organizational Research - Research in the Sociology of Organizations 38, 131–160

Jensen, M.B., Johnson, B., Lorenz, E., Lundvall, B.Å., 2007. Forms of knowledge and modes of innovation. Research Policy 36, 680–693.

Kogut, B., Zander, U., 1994. What Firms Do? Coordination, Identity, and Learning. Organization Science 7, 502-518.

Krueger, D., Kumar, K. 2004a. Skill-Specific rather than General Education: A Reason for US-Europe Growth Differences? Journal of Economic Growth 9, 167–207.

Krueger, D., Kumar, K. 2004b. US–Europe differences in technology-driven growth: quantifying the role of education. Journal of Monetary Economics 51, 161–90.

Meuer, J, Rupietta, C., Backes-Gellner, U., 2015. Layers of co-existing innovation systems. Research Policy 44, 888-910.

Misangyi, V.F., Acharya, A.G., 2014. Substitutes or complements? A configurational examination of corporate governance mechanisms. Academy of Management Journal 57, 1681-1705.

Muehlemann, S., Pfeifer, H., Walden, G., Wenzelmann, F., Wolter, S. C. 2010. The Financing of Apprenticeship Training in the Light of Labor Market Regulations. Labour Economics 17, 751-874.

Ragin, C., Davey, S., 2014. Fuzzy-Set/Qualitative Comparative Analysis 2.5. Irvine, California: Department of Sociology, University of California.

Ragin, C. Fiss, P., 2008. Net effects versus configurations: an empirical demonstration. In: Ragin C. (Ed.) Redesigning social inquiry: fuzzy sets and beyond. 190-212.

Rupietta, C. Backes-Gellner, U., 2015. High quality workplace training and innovation in highly developed countries, Economics of Education Working Paper Series no. 74.

Schönfeld, G., Wenzelmann, F., Dionisius, R., Pfeifer, H., Walden, G., 2010. Kosten und Nutzen der dualen Ausbildung aus Sicht der Betriebe. Bundesinstitut für Berufsbildung, Bonn.

Stevens, M., 1994. A Theoretical Model of On-the-Job Training with Imperfect Competition. Oxford Economic Papers 46, 537–62.

Von Bardeleben, R., Beicht, U., Fehér, K., 1995. Betriebliche Kosten und Nutzen der Ausbildung: repräsentative Ergebnisse aus Industrie. Handel und Handwerk. Bertelsmann, Bielefeld.

Wolter, S. C., Mühlemann, S., Schweri, J., 2006. Why some firms train apprentices and many others not, German Economic Review 7, 249-264.